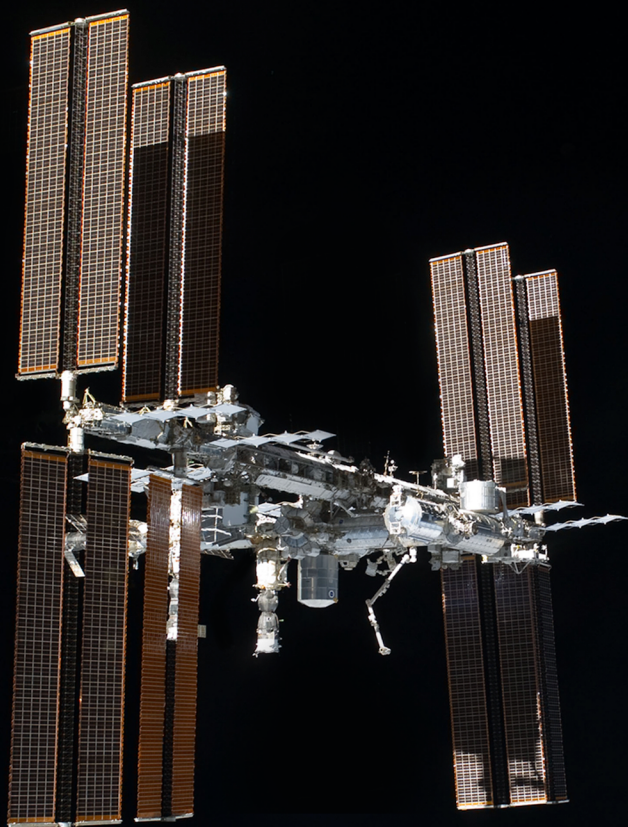




A Researcher's Guide to:

I N T E R N A T I O N A L S P A C E S T A T I O N

Technology Demonstration



This International Space Station (ISS) Researcher's Guide is published by the NASA ISS Program Science Office.

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Cover and back cover:

- a. The ISS is seen from an unusual angle during the shuttle Atlantis' final fly-around in July 2011. The moon is visible above and to the right of the station.*
- b. Art concept of Robonaut (R2) hand reaching out to EMU gloved hand with space and stars in the background. Photo taken in Building 32 - Robonaut Lab at NASA Johnson Space Center.*
- c. Several tiny satellites are featured in this image photographed by an Expedition 33 crew member on the ISS. The satellites were released outside the Kibo laboratory using a Small Satellite Orbital Deployer attached to the Japanese module's robotic arm on Oct. 4, 2012. Japan Aerospace Exploration Agency astronaut Aki Hoshide, flight engineer, set up the satellite deployment gear inside the lab and placed it in the Kibo airlock. The Japanese robotic arm then grappled the deployment system and its satellites from the airlock for deployment. A portion of the station's solar array panels and a blue and white part of Earth provide the backdrop for the scene.*

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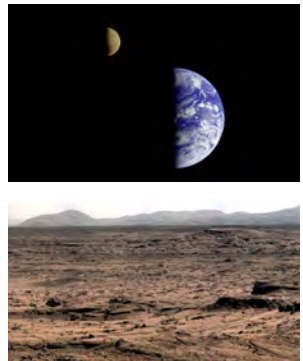
Preface

The mission of the International Space Station (ISS) Program is to advance science and technology research, expand human knowledge, inspire and educate the next generation, foster the commercial development of space and demonstrate capabilities to enable future exploration missions beyond low Earth orbit (LEO).

To execute this mission — specifically, technology advancements — the ISS Program is utilizing the space station as a test bed to demonstrate operational techniques and capabilities, and demonstrate technologies and advanced systems that benefit space science capabilities and human and robotic exploration beyond LEO. Working with the international exploration community, the Global Exploration Roadmap was developed to provide an internationally, phased approach defining capabilities that will be needed for future exploration. Demonstration of these advanced capabilities is a primary objective of the ISS Program mission.

This booklet has been developed to provide prospective technology and advanced system developers the information that will aid in the formulation of demonstration concepts and as an introduction of station capabilities, characteristics and processes.

The following pages begin by describing the technology development areas of greatest interest to the National Aeronautics and Space Administration (NASA) followed by descriptions of ISS interfaces and the manifesting process. Finally, points of contact are identified before a description of the processes and capabilities that are available to selected and manifested payloads.



Top right: This panorama is a mosaic of images taken by the Mast Camera (Mastcam) on the NASA Mars rover Curiosity while the rover was working at a site called "Rocknest" in October and November 2012. Image Credit: NASA/JPL-Caltech/Malin Space Science Systems. **Bottom Right:** This picture of the Earth and Moon in a single frame, the first of its kind ever taken by a spacecraft, was recorded September 18, 1977, by NASA's Voyager 1 when it was 11.66 million km (7.25 million miles) from Earth.

ISS Technology Demonstration Program

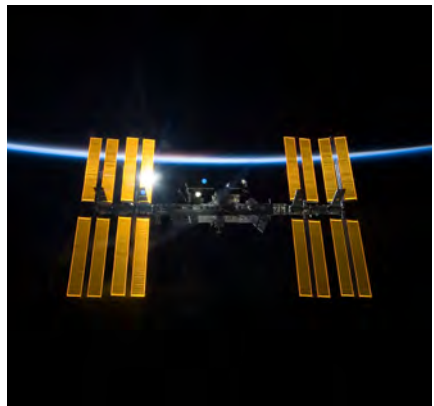
Overview

The ISS Program provides an infrastructure capable of demonstrating prototypes and systems that may advance spaceflight technology readiness. The space station, the in-orbit crew, the launch and return vehicles, and the operation control centers are all supporting the demonstration of advanced systems and operational concepts that will be needed for future exploration missions.

The ISS is the only long-duration platform available in the relevant space environment with an integrated space systems architecture that can be used to demonstrate advanced technologies and operations concepts. Working in close cooperation with the exploration community, the ISS Program is enabling technology and systems investigations in support of future exploration endeavors. NASA has identified 11 exploration technology areas of interest that ISS is capable of supporting. These 11 technical areas are described in the following pages. Details of exploration and technology needs are documented in *NASA Technical Paper TM-2012-217670*.

The ISS Program aims to demonstrate these and other technologies on the space station where they can be evaluated without significant risk to crew or vehicle in order to accelerate development and reduce risks for future exploration missions.

Project developers who have formulated a technology demonstration project and are ready to contact the ISS Program should reference the “Application to ISS Technology Demonstration” section starting on page 32 of this book.



Technology Readiness Level Advancement

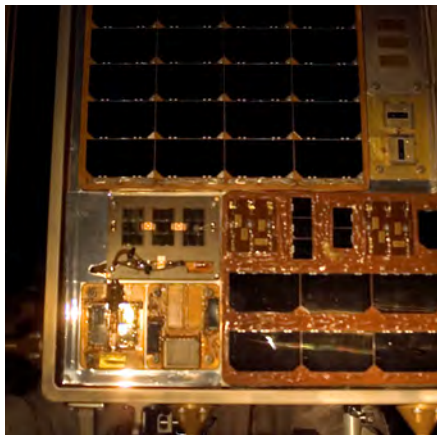
The ISS Laboratory is available to conduct research and/or engineering investigations to advance Technology Readiness Levels (TRL) by demonstrating system performance in the unique space environment offered by station or its visiting vehicles. Additionally, station-based demonstrations support proofing the concepts of operations, training, crew interfaces and logistics as well as maintainability and reliability. Performing these demonstrations on the space station provides an opportunity to obtain operational knowledge in a relevant environment without the added costs and risk associated with integrating a new technology or advanced system into an operational system.

In-Space Propulsion

Systems for in-space propulsion can benefit from in-space demonstration by gaining operational run time in the microgravity, vacuum and thermal environments of space while gaining experience in fuel flow management and performance. Demonstrations providing integrated system operations or subsystem investigations demonstrating supporting elements of a system can be performed.

If scaled to not adversely impact ISS, in-space propulsion systems can be demonstrated on the space station, potentially on visiting vehicles or deployed free fliers.

Space Power and Energy



Solar array and solar cell demonstrations in space are important because they allow the demonstration of performance absent the solar filtering and diffusion caused by the atmosphere. At the same time, they provide the appropriate thermal and dynamic loading conditions that will be seen in an implemented system.

Fuel cells and other systems that operate with fluids, especially two-phased fluids, benefit from demonstrating performance in the microgravity environment.

Robotics, Tele-Robotics and Autonomous Systems



Robotic and tele-robotic systems operating in and around a spacecraft, with or without crew-robot interaction, will demonstrate performance and operational concepts of robotic systems in the manned and unmanned spacecraft environments.

Tele-robotic demonstrations on ISS show the ability to perform and develop concepts of operation for an in-space crew to perform remote operations.

Communication and Navigation




Navigation systems can be demonstrated on ISS with system performance compared to the spacecraft's known position. Advanced or automated rendezvous and docking systems can be demonstrated with ISS and visiting vehicles or dedicated free fliers.

Communication systems can utilize the space station infrastructure to demonstrate delay tolerance and the elimination of space communication architecture bottlenecks, thus increasing throughput of the integrated systems.

Life Support and Habitation Systems



The job of maintaining a habitable environment for the crew over the duration of a human spaceflight mission is performed by Environmental Control & Life Support Systems (ECLSS). Living in space for long durations with little or no resupply from Earth is a fundamental capability that is being matured through day-to-day operations on the only platform capable of that task – ISS. For long-duration exploration beyond LEO, spacecraft systems must provide a stable, self-contained micro-environment around the clock by revitalizing the air, collecting



and processing wastewater streams to recover and provide safe drinking and hygiene water for the crew, and managing solid wastes (metabolic and trash). ISS presents the opportunity to perform limited upgrades to the current systems to increase operational availability and reduce system mass, consumables and power needs beyond the current capability. At the same time, ISS provides a directly relevant operating environment to perform demonstrations of technologies and prototype systems to reach capabilities necessary to enable an exploration-class mission. Operational demonstrations aboard ISS will ensure that the ECLSS needed for exploration beyond LEO has been verified properly to keep the crew alive and safe for more than a year away from Earth.

Exploration Destination Systems

Human Exploration Systems are exploration-specific capabilities that do not clearly fall into other technology categories. As such, the technologies in this area are diverse and expansive. Many of these technologies are related to extravehicular activity (EVA), or spacewalks, and general habitation. These systems can benefit from the microgravity environment and utilization within the operation of the station-habitable environment.

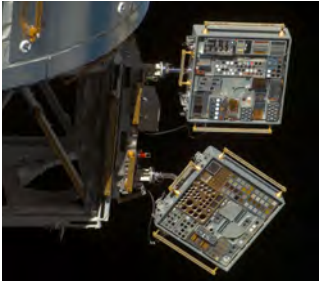
Science Instruments

As advances in scientific technology enable more capable science and sensor systems, prototype systems can be demonstrated on ISS to evaluate performance in the space environment and in relevant conditions. On ISS, these systems can be evaluated by the in-orbit crew or within the existing station commanding and data infrastructure, such that confidence can be gained and risks reduced in the system before it is used on a dedicated science mission. Additionally, science system demonstrations can be used to evaluate and assist in down selecting systems that are under consideration.

Entry, Descent and Landing Systems

ISS visiting vehicles re-enter Earth's atmosphere following station-docked missions. There are several methods to deploy small satellites from the space station that will re-enter the atmosphere. These opportunities can be used to demonstrate capabilities and techniques and increase knowledge of atmospheric re-entry.

Materials, Structures and Manufacturing



Long-duration exploration missions will experience the ultraviolet, thermal and energized particle radiation environment of space requiring the use of materials on spacecraft that can survive these harsh conditions. ISS offers long-duration space exposure in which materials can be evaluated. Space station return vehicles can also be utilized to expose sample materials being considered for the return environment.

Thermal Management Systems

Besides re-entry thermal protection, spacecraft thermal technologies are needed to maintain cryogenic systems and thermal control of a spacecraft's systems and internal environment.

Cryogenic systems contain fluids in two-phased regimes. Thermal insulation and recapture, fluid flow, and level measurement of these fluids are uniquely affected by the space and microgravity environment. Demonstrating system capabilities in the relevant environment of ISS would demonstrate needed exploration capabilities.

Heat rejection technology should operate efficiently and reliably across a wide range of thermal environments. Future spacecraft will benefit from advanced technologies and systems that can efficiently maintain heat loads in both the hot and cold environments of space.

Operational Processes and Procedures

ISS is continuously managed and operated from several distributed control centers around the globe. The processes, procedures and software tools used in station operations are continuously evolving and maturing with future missions in mind. Where possible, operational concepts (processes, software tools, training and procedures) are advancing toward the type of operations expected from an exploration mission, with delayed communications, increased in-space crew autonomy and reduced routine ground-to-space interactions.

ISS Accommodations

ISS provides investigators with a variety of accommodations and resources. Accommodations include: internal, or pressurized habitable volume; external, exposure to the space environment; transportation to and from the space station and deployable options.

A few of the accommodations more commonly utilized by technology demonstration payloads are highlighted here. For a more comprehensive description of the facilities and accommodations on ISS, the reader is referred to the International Space Station Facilities Book.

Internal

Internal to ISS, the technology and system demonstrations will be exposed to the nominal habitable station environment.

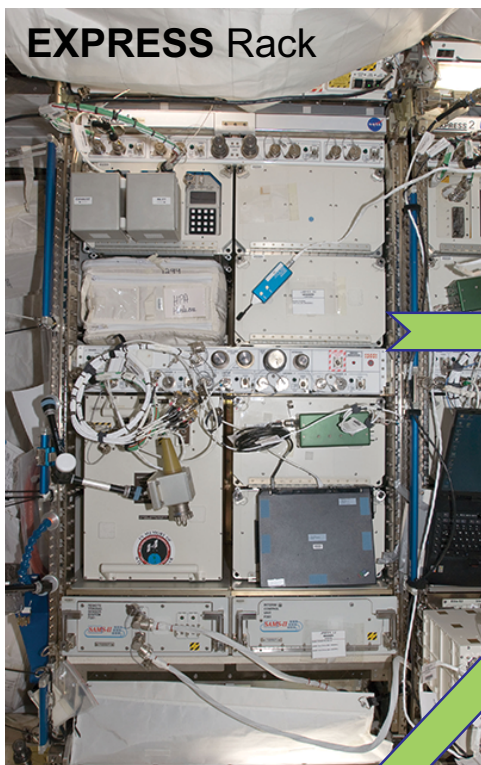
Expedite the Processing of Experiments for Space Station (EXPRESS) Rack

Internal to the space station habitable volume, technology demonstrations can be installed in the EXPRESS racks. EXPRESS racks support multi-discipline investigations and provide several resources that can be utilized in the technology demonstration.

EXPRESS Rack Resources

System	Middeck Locker Locations	ISIS Drawer Locations	Rack-Level Accommodations
Structural	Volume: 2 cubic feet Internal Dimensions: 20.32 x 17.34 x 9.97 inches	Volume: 1.26 cubic feet Internal Dimensions: 23.25 x 16.62 x 6.0 inches	8 Mid deck Lockers 2 ISIS Drawers (4 Panel Unit)
Power	28 Vdc, 0 - 500 W	28 Vdc, 0 - 500 W	2000 Watts 28 Vdc power
Air Cooling	< 200 Watts	< 100 Watts	1200 Watts
Thermal Control System Water Cooling	500 Watts (2 positions per rack)	500 Watts (2 positions per rack)	2 positions per rack
Command & Data Handling	RS422 Analog Ethernet 5 Vdc Discrete	RS422 Analog Ethernet 5 Vdc Discrete	RS422 Analog Ethernet 5 Vdc Discrete
Video	NTSC/RS170A	NTSC/RS170A	NTSC/RS170A
Vacuum Exhaust System	1 payload interface per rack	1 payload interface per rack	1 payload interface per rack
Nitrogen	1 payload interface per rack	1 payload interface per rack	1 payload interface per rack

EXPRESS Rack



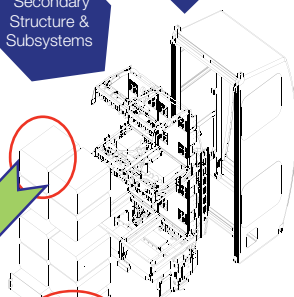
Sub Rack size payload capability with standard utilities such as power, data, cooling and gases

EXPRESS 8/2 Configuration

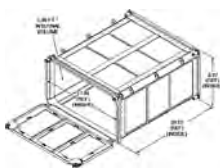
8/2 Payload Configuration
(8 Middeck Lockers,
2 Powered ISIS Drawers)

International
Standard
Payload Rack

Secondary
Structure &
Subsystems



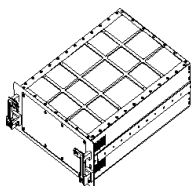
Middeck Locker



Features

- 4 rear captive fastener attachments
- Friction hinge
- Dual door locks
- Installation tool guides on 4 corners
- Weight – 12 lbs

International Sub rack Interface Standard Drawer



Features

- 4 PU (Panel Unit)
- Blind Connectors
- Locking Handles
- Weight – 27 lbs
- Rated to at least 37 lbs

Station to Internal Facility Rack Resources

The resources listed below are available in various rack locations on ISS.



Aisle-Deployed Payloads

In some cases, small technology demonstrations can be installed or demonstrated

POWER	3, 6 or 12kw, 114.5-126 voltage, direct current (VDC)	
DATA	Low Rate	MIL-STD-1553 bus 1 Mbps
	High Rate	100 Mbps
	Ethernet	10 Mbps
	Video	NTSC
GASES	Nitrogen	Flow = 0.1 kg/min minimum; 517-827 kPa nominal; 1379 kPa, maximum
	Argon, carbon dioxide, helium	517-768 kPa nominal; 1379 kPa, maximum
COOLING LOOPS	Moderate Temperature	16.1°C – 18.3°C
	Flow Rate	0 – 45.36 kg/h
	Low Temperature	3.3°C – 5.6°C
	Flow Rate	233 kg/h
VACUUM	Venting	10-3 torr in less than 2h for single payload of 100 L
	Vacuum Resource	10-3 torr (to maintain vacuum only, not for venting)

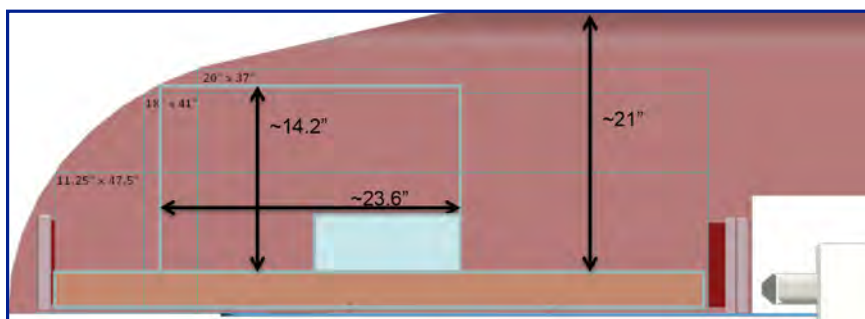
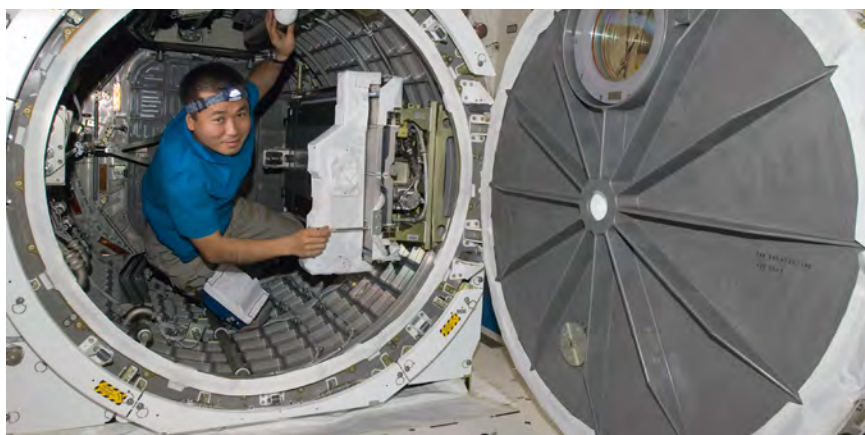
outside of racks in a manner that does not interfere with crew passage or operations. In these instances, power and data resources can be provided to a payload from an EXPRESS Rack.

Internal/External

Japanese Experiment Module (JEM) Airlock

The JEM is unique within ISS in that it has an airlock, which is located on the end of the JEM that faces the JEM Exposed Facility (JEM-EF). The airlock allows the transfer of payloads between the internal pressurized cabin and space. The JEM airlock can accommodate a payload up to 300 kg in mass that fits within the dimensions of the airlock. The general dimensions and form of the airlock volume are shown on the next page and are 32 inches in width.

A slide table allows the JEM-EF robotic arm to access the payload. The JEM-EF

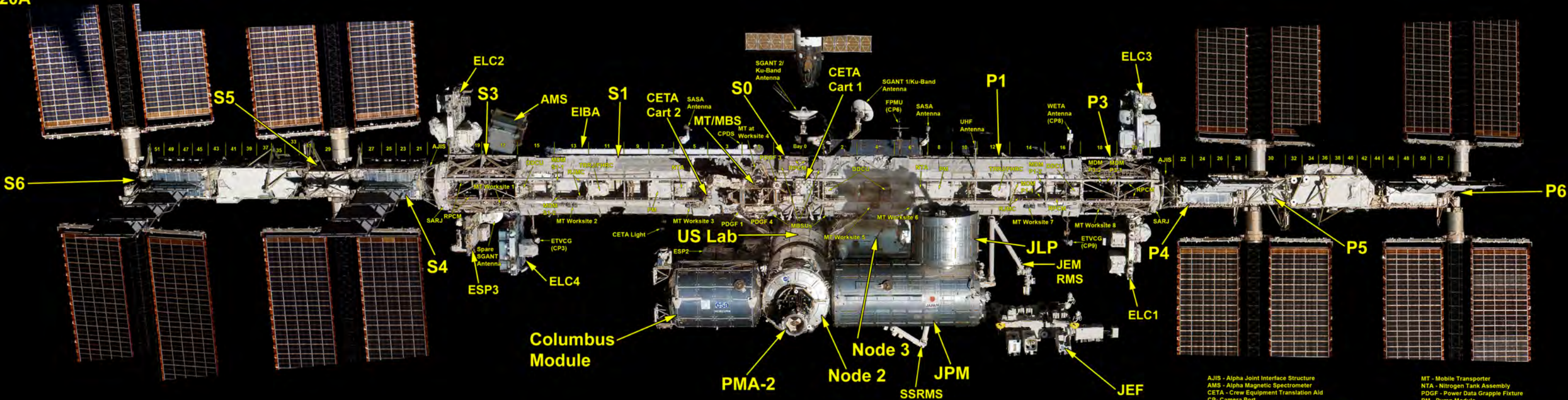


arm moves the payload between the JEM airlock and external ISS locations. JEM airlock usage is negotiated on an as-needed basis.

External

ISS provides a variety of external sites and services to conduct payload investigations.

Modified (1-31-13) - Forward Side of ISS
AF-20A



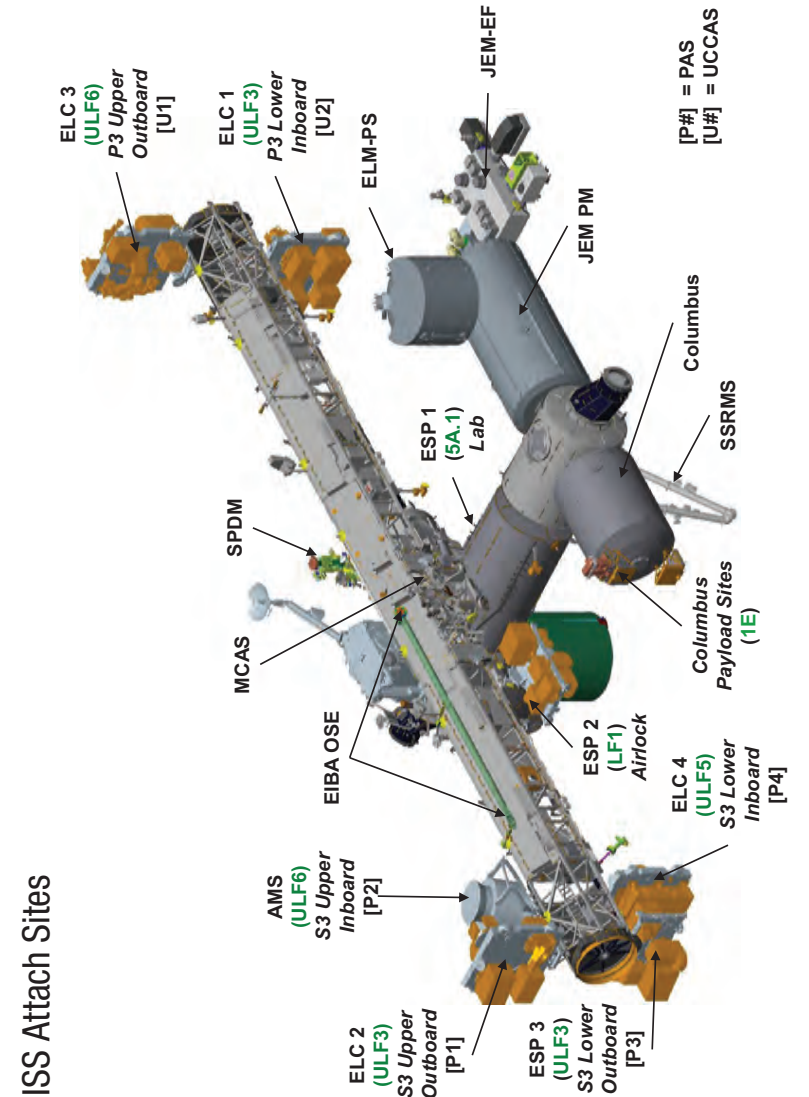
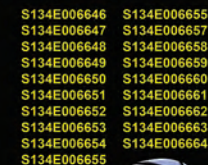
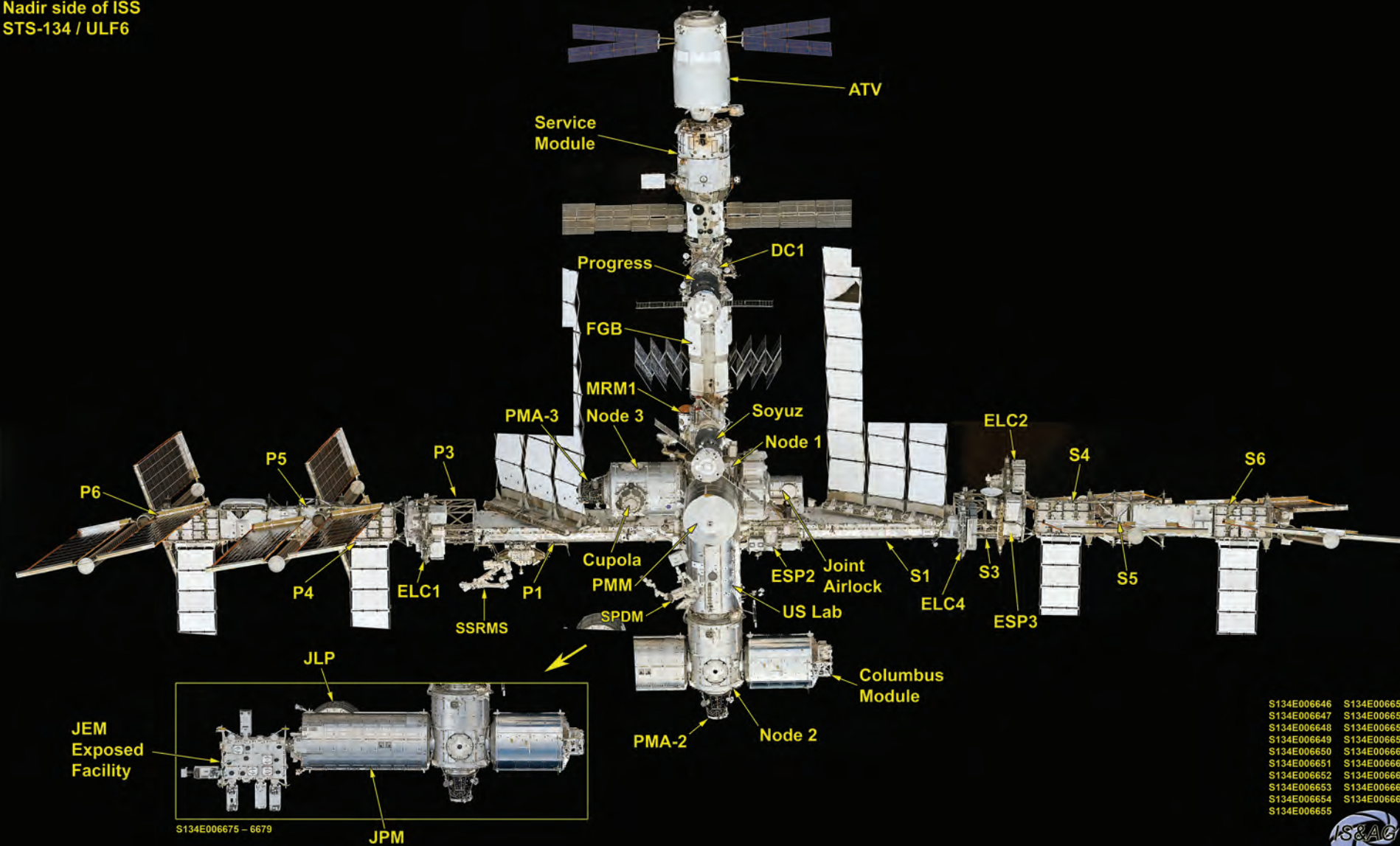
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Note: The EIBA, AMS, ELC3 and ELC4 have been added to the mosaic from images taken during STS-134 (S134E010570, S134E010580 and S134E010582). The SGANT 2 was added to the mosaic from image S133E010564.

- AJIS - Alpha Joint Interface Structure
- AMS - Alpha Magnetic Spectrometer
- CETA - Crew Equipment Translation Aid
- CP - Camera Port
- CPDS - Charged Particle Directional Spectrometer
- DDCU - DC-DC Converter Unit
- EIBA - Enhanced Integrated Boom Assembly
- ELC - External Logistics Carrier
- ESP - External Stowage Platform
- ETVCG - External Television Camera Group
- FHRC - Flex Hose Rotary Coupler
- FPMU - Floating Potential Measurement Unit
- JEF - JEM Exposed Facility
- JEM RMS - Japanese Experiment Module Remote Manipulator System
- JLP - Japanese Experiment Logistics Module - Pressurized Section
- JPM - JEM Pressurized Module
- MBS - Mobile Remote Servicer Base System
- MBSU - Main Bus Switching Unit
- MDM - Multiplexer Demultiplexer
- MT - Mobile Transporter
- NTA - Nitrogen Tank Assembly
- PDGF - Power Data Grapple Fixture
- PM - Pump Module
- PMA-2 - Pressurized Mating Adapter
- RJMC - Rotary Joint Motor Controllers
- RPCM - Remote Power Control Module
- SARJ - Solar Alpha Rotary Joint
- SASA - S-band Antenna Support Assembly
- SGANT - Space to Ground Antenna
- SSRMS - Space Station Remote Manipulator System
- TRRU - Thermal Radiator Rotary Unit
- UHF - Ultrahigh Frequency
- WETA - Wireless Video System External Transceiver Assembly



**Nadir side of ISS
STS-134 / ULF6**





EXPRESS Logistics Carrier (ELC)

Technology demonstrations performed externally on ISS can be attached to one of the ELCs. The ELC locations offer viewing options ranging from nadir to zenith and points in between. Payload demonstrations attaching to the ELC will require the use of a Flight Releasable Attachment Mechanism (FRAM). The FRAM provides mechanical, electrical, thermal, data, EVA, and robotic interfaces to ISS.

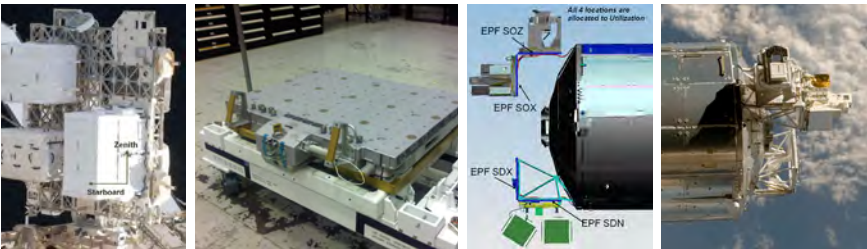
ELC External Research Accommodations

ELC Single Adapter Resources	Mass capacity	227 kg (500 lb)
	Volume	1 m3
	Power	750 W, 113 – 126 Vdc; 500 W at 28Vdc per adapter
	Thermal	Active heating, passive cooling
	Low-rate data	1 Mbps (MIL-STD-1553)
	Medium-rate data	6 Mbps (shared)
	Sites available per ELC	2 Sites
	Total ELC sites available	8 Sites

The medium rate data interface will be updated at each ELC location to 100 Mbps two-way wireless LAN.

Columbus Exposed Facility (EF)

Located on the starboard side of space station, the European Space Agency (ESA) Columbus module also provides an external facility to accommodate external technology demonstrators. Similar to the FRAMs, the technology demonstration payload will be provided a Columbus External Payload Adapter (CEPA) to interface to the space station services.

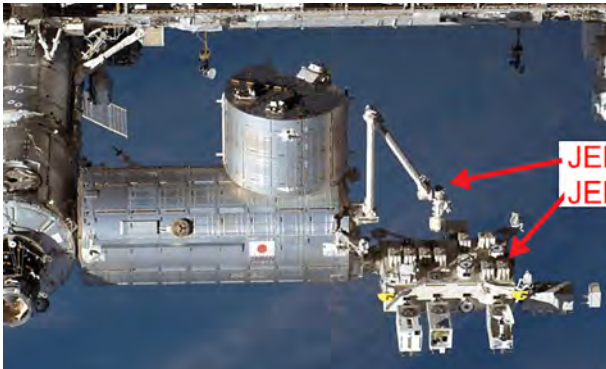


Columbus EF Resources

Location	Viewing	Payload Size	Power	Data
SOZ	Zenith	226kg +CEPA	1.25 kW at 120VDC 2.5 kW max	1553 -1 Mbs ethernet - up to 10 Mbs
SOX	Ram			
SDX	Ram			
SDN	Nadir			

JEM-EF

On the port side of ISS, the JEM provides accommodations for attaching external payloads. The JEM-EF is a multipurpose experiment platform where various investigations/demonstrations can be performed. The JEM-EF has 12 attachment ports for external payload and can accommodate up to ten payloads simultaneously. The attachment port on the JEM-EF provides mechanical, thermal and electrical interfaces to the attached payloads. This interface mechanism is called Experimental Exchange Unit (EEU).



JEM RMS
JEM External Facility

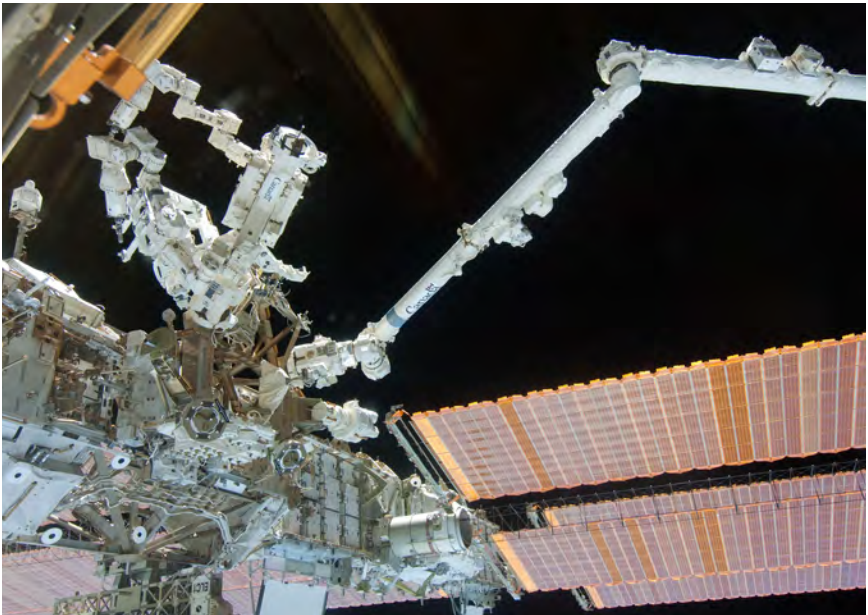
JEM External Resources

JEM EF Resources	Mass Capacity	550 kg (1150 lb) at standard site 2250 kg (5550 lb) at large site
	Volume	1.5 m ³
	Power	3 – 6 kW, 113 – 126 Vdc;
	Thermal	3 – 6 kW cooling
	Low-rate data	1 Mbps (MIL-STD-1553)
	High-rate data	43 Mbps (shared)
	Sites available to NASA	5 Sites

Robotic Capabilities

EVA (spacewalks) at ISS are reserved to address critical maintenance activities. With limited spacewalk opportunities, external technology demonstration payloads must be robotically manipulated and installed. Currently, there are two robotic manipulator systems aboard ISS. These robotic systems were responsible for much of the construction of the space station and are now available for payload utilization.

Mobile Servicing System (MSS)



The MSS is part of the Canadian Space Agency's contribution to ISS. It consists of the Space Station Remote Manipulator System, the Special Purpose Dexterous Manipulator, and the Mobile Base System. These, along with two robotics workstations, to operate the robotic systems from inside the space station, and the Mobile Transporter, which is used to transfer hardware along the length of the truss, are now assisting with payload utilization.



JEM Robotic Manipulator System (RMS)

The JAXA-provided RMS resides on the JEM-EF. This manipulator can be used to remove payloads from the JEM airlock for placement on the EF and can also be used with ISS small satellite deploying systems to launch deployable payloads.

Access to the External Environment

Payloads can gain access to the external environment in one of two ways. For large payloads that are destined for one of the payload accommodation sites, they can be launched to ISS inside the SpaceX Dragon Trunk. Once the Dragon has been captured and berthed to the space station, the MSS can be used to remove the payload and install it at its destination. Smaller payloads can be launched to ISS in the pressurized environment in one of the many launch vehicles and then transferred to the space environment through JAXA's JEM airlock.

Robotic Interfaces

FRAMs and CEPAs are provided to technology payload developers as Government Furnished Equipment. Robotic interfaces are pre-integrated with the FRAMs and CEPAs.

Special Considerations

Special consideration should be given to externally-attached demonstration payloads in the following areas:

Contact Loads - Payloads that are maneuvered with a robotic manipulator are generally moved into and out of areas of tight clearance with station hardware. While every effort is made to prevent collision, there are some unpredictable failure cases where contact may occur. Ideally, payloads should be designed to withstand the energy imparted from this inadvertent contact.

Thermal Environment - In an effort to preserve as much in-orbit crew time as possible, a majority of in-orbit robotic operations are performed by ground controllers from the Mission Control Center (MCC). Applied constraints on the ground-controlled robotic motion can result in a long-duration transit to the payload's destination. Given the thermal extremes that can be experienced during this timeframe, a payload developer should consider this when designing a payload's thermal control system.



Deployable Small Satellites

ISS has limited capability to deploy small satellites from the space station for free flight and ultimate re-entry to Earth’s atmosphere.

	Size, Approximate mm (Inches)	Mass (Max, of Deployed satellite)	Location of Deployment
J-SODD	1U - 100 x 100 x 113.5 mm (3.9 x 3.9 x 4.7 inches) 2U - 100 x 100 x 227.0 mm (3.9 x 3.9 x 8.9 inches) 3U - 100 x 100 x 340.5 mm (3.9 x 3.9 x 13.4 inches)	1.33 Kg/1U	Deployed from ISS (JEM EF) Currently in-orbit
CYCLOPS	1117.6 x 762 x 279.4-533.4 mm (44L x 30W x 11-21H inches)	100 kg	Deployed from ISS (JEM EF) In-orbit post SpX3 launch
Space X	1U - 100 x 100 x 100 mm (3.9 x 3.9 x 3.9 inches) 2U - 100 x 100 x 200 mm (3.9 x 3.9 x 6.8 inches) 3U - 100 x 100 x 300 mm (3.9 x 3.9 x 10.7 inches)	1.33 kg/1U	Deployed from Space X prior to ISS docking Available post SpX3

Software and Avionics, ISS Command and Data Handling

Health and Status Data

All payloads are required to generate health and status data and transmit it to the ground. Health and status data includes all of the parameters needed by Payload Operations on the ground to insure that the payload is operating normally and correctly responding to commands.

Broadcast Ancillary Data (BAD)

MIL-STD-1553 System distributes ISS BAD to all payloads Remote Terminals (RTs). BAD data contains most of ISS vehicle information that experiments need like station location, position and pointing vector information. In addition, the ISS BAD data contains information about the current pressure, temperature and other environmental information data about the space station modules where payloads are located. If there is data a payload needs that is available and not currently in BAD, it is possible to have it added to BAD if the request is made early enough.

Unique Ancillary Data

Data available from within the Payload Multiplexer De-Multiplexer (PL MDM) that is not present in BAD can be transmitted to the payload via the definition of a unique ancillary data service. When initialized in the PL MDM, data is transmitted to the payload on the 1553 bus.

ISS Data Interfaces

ISS Payload Data Links

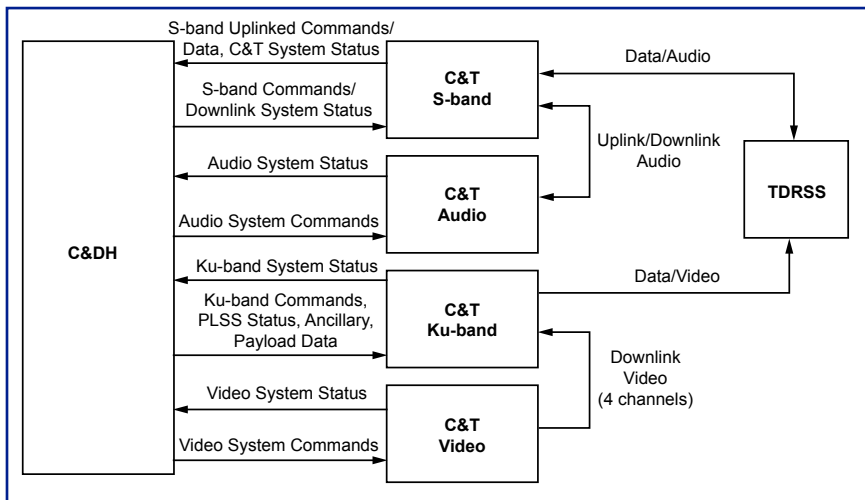
Data Interface	Format	Data Rate (1)	Notes
Low Rate Data Link (LRDL)	MIL-STD-1553	12kbps	Nominally used for payload commanding and to gather health and status. Limited telemetry downlink is also available.
Medium Rate Data Link (MRDL)	Ethernet 802.3	10/100Mbps	Ethernet input and output (downlink) is available at most internal locations. Downlink is via UDP is available at most external sites.
High Rate Data Link (HRDL)	TAXI Fiber-optic	100Mbps	HRDL input and output is available at most internal sites. HRDL is not available at most external sites.
Video (2)	NTSC	12.5Mbps	Only available at internal International Standard Payload Rack ISPR sites.
Wireless Data Link	WiFi Ethernet 802.11b/g	100Mbps	Available to internal and external sites that are within range of the access point.

Table Notes: (1) All station data links are shared resources. The data rate listed is the maximum data rate the link can support.
(2) Because of the high demand for video downlink and high bandwidth use, it is recommended that the experiments encode and downlink video via MRDL when possible.

Typical Utilization of ISS Downlink Shared by all Payload Users:

1. 37.5 Mbps of video (3 lines of video at 12.5 Mbps each)
2. 8 Mbps of MRDL data (Science return)
3. 5 Mbps for payload still imagery downlink
4. 20 Mbps utilized for payload data recorded over Loss of Signal (LOS)

ISS Command and Data Handling C&DH Interfaces to the Communications and Tracking System



Data Downlink Availability Downlink and Storage

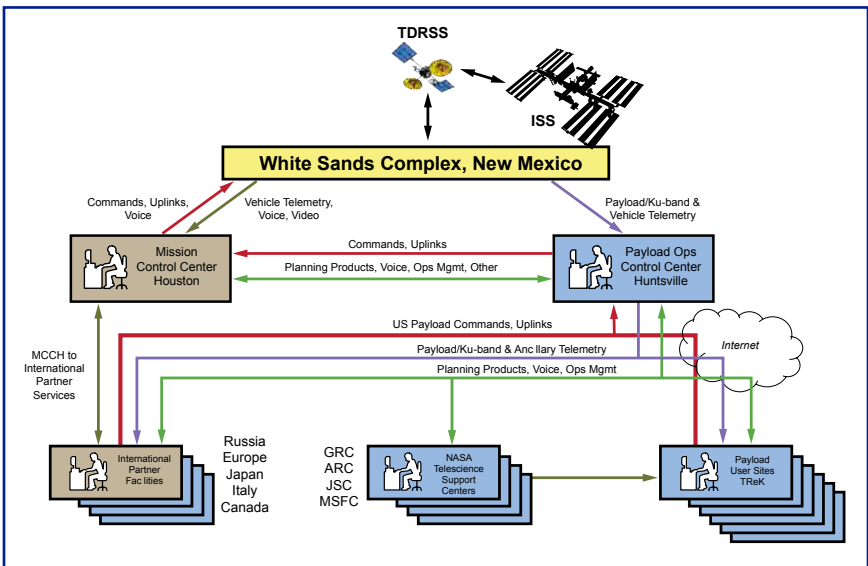
Tracking and Data Relay Satellite System (TDRSS) S-Band and Ku-Band coverage varies based on ISS attitude, location and beta angle. Typically, coverage ranges from 70 to 85 percent. Payloads should plan to internally store and retain any data essential for the success of the experiment until it can be verified that the data has been transmitted to the principle investigator. Downlinked data is stored by payload operations and can be transmitted to the payload user if they are unable to receive the data when it is downlinked. During periods of LOS between station and TDRSS, the ISS Integrated Communications Unit (ICU) (1.6 Tbits total storage capability) nominally records payload data that would have been transmitted during that LOS. The ICU will routinely store all low- to medium-rate payload data during TDRSS communication outage periods, and some or most of the high-rate payload data. This depends on how much data is being downlinked and how much of the data can be downlinked when station has Acquisition of Signal with TDRSS.

Command/Data Latency

During periods of TDRSS coverage, the following command uplink and data downlink latencies can be achieved, if automatic enabling of payload commanding during Ku-band coverage has been worked out ahead of time with NASA Marshall Space Flight Center Payload Operations Integration Facility:

1. Data Downlink Latency, station payload-to-payload developer remote site:
5 seconds
2. Command Uplink Latency, payload developer remote site to station payload:
10 seconds (with payload command confirmation – up to 15 seconds round trip).

Data Security and Encryption



Commands and data sent to ISS via S-Band is encrypted at MCC – Houston prior to transmission for security reasons. Station does not offer any encryption data that is downlinked via Ku-Band. Payload data that must be protected as crew health or medically sensitive data is and must be properly protected by the payload prior to it being downlinked.

Payload Software and Displays

A unique payload software Interface Control Document (ICD) is developed for each payload to document the software and data interfaces. Payloads are required to contain and control all of their hazards internally and are not permitted to use any station C&DH interface or data as a required control of a hazard. Software and firmware used in support of an experiment on ISS must be configuration and quality controlled. Software that will need to be uplinked to ISS during the mission must be virus scanned and delivered to NASA prior to being uplinked. ISS uses a single laptop on orbit; currently, it is the IBM T61p. Displays that are to be used by the crew in-orbit in support of an experiment must be delivered to NASA well in advance of being used. Delivery cycle requirements are established to a standard template based on the flight increment the payload is to be flown, installed and operated. Payload displays are reviewed by the crew for usability and in support of payload training long before the start of the increment.

Telescience Resource Kit – Payload Operations Interface

The Telescience Resource Kit (TREK) is a suite of PC-based software applications provided to payload developers by the ISS Program that is used by scientists and engineers to monitor and control payloads aboard the space station.

The PC running the TREK software can be located anywhere in the world. This provides a way for scientists and engineers to monitor and control experiments located in space from their offices and laboratories at home.

TREK can be used to receive payload data from ISS, distributed by the Payload Operations and Integration Center and to perform local data functions such as processing the data, storing it in local files and forwarding it to other computer systems.

Users can extend TREK capabilities by using the TREK Application Programming Interface together with commercial software products to utilize local telemetry and command functions.

ISS Characteristics

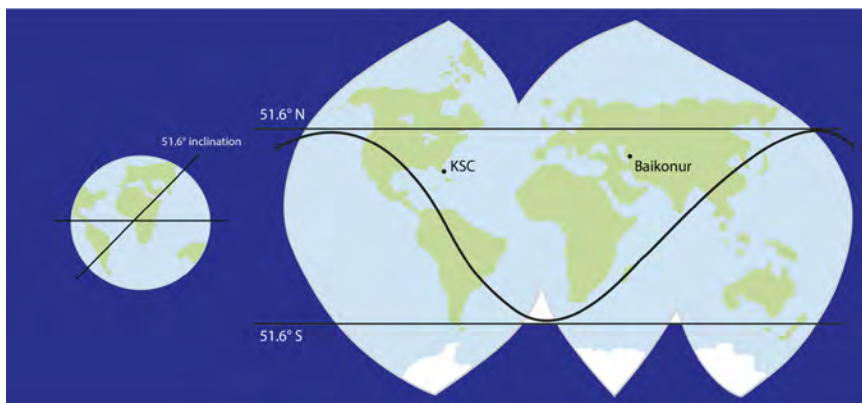
Internal Atmosphere

The nominal station atmosphere is shown in the table below:

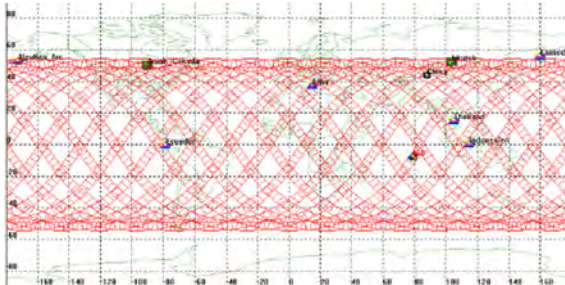
Atmospheric Conditions on ISS	Nominal Value
Pressure	14.7 PSI
Dew point	4.4 to 15.6°C (40 to 60°F)
Carbon dioxide partial pressure	5.3 mm Hg Peak exposure 7.6 mm Hg
Oxygen partial pressure	3.1 PSI ppO2
Cabin air temperature	17 to 28°C (63 to 82°F)

Orbit Characteristics

Over the course of 72 hours and terrestrial weather conditions permitting, all geographic locations between 51.6 north and south latitude can be observed. ISS provides coverage of 85 percent of the Earth's surface and 95 percent of the world's populated landmass every one to three days.



The station altitude generally varies with the solar cycle, with the altitude maintained higher during solar maximum. Eccentricity of the station's orbit is maintained at <0.003 . In support of visiting vehicles, the altitude is adjusted to accommodate the visiting vehicles' performance parameters. In general, the space station altitude will remain within 395-417 km (245-259 miles).



ISS coverage in 24 hrs for a 70°-swath optical payload. (Courtesy of ESA)

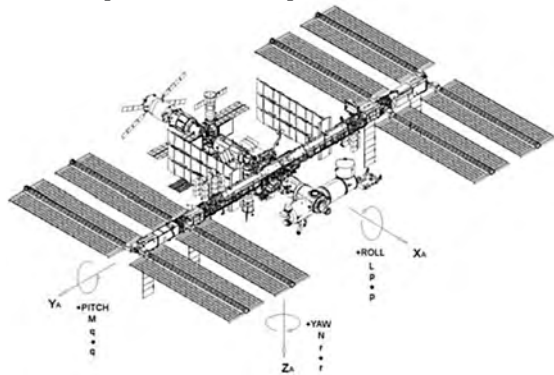
Guidance, Navigation and Control Characteristics

ISS Attitude Torque Equilibrium Attitude (TEA) & Wobble Oscillation Description – for stage configurations in the foreseeable future (i.e., no orbiter or orbiter-sized vehicles docked on the space station), the predicted TEA ranges are:

Roll: -1.0~+3.0 deg.

Pitch: -7.0~+2.0 deg.

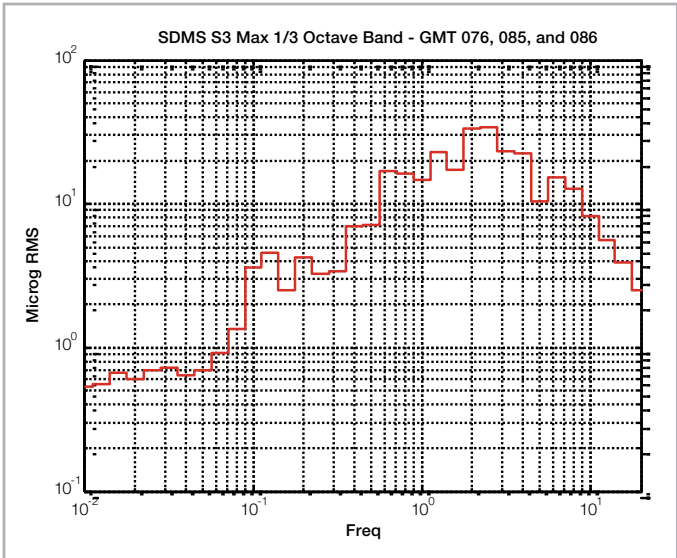
Yaw: -15~+15 deg.



Performance Descriptions	Peak to Peak Attitude Oscillations Per Orbit			Peak Attitude Variation from Steady State Orbit Average Attitude		
	Roll (X) (deg)	Pitch (Y) (deg)	Yaw (Z) (deg)	Roll (X) (deg)	Pitch (Y) (deg)	Yaw (Z) (deg)
Non-Micro-Gravity (Assembly Stages) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement	10.0	10.0	10.0	+/- 5	+/- 5	+/- 5
Micro-Gravity (Assembly Complete) Non-Propulsive (Momentum Manager) Attitude Control Performance Requirement	7.0	7.0	7.0	+/- 3.5	+/- 3.5	+/- 3.5
Typical Steady-State Performance of Minimum CMG momentum oscillation Momentum Manager Controller	1.6	1.6	2.0	+/- 0.8	+/- 0.8	+/- 1
Typical Steady-State Performance of Minimum Attitude oscillation Momentum Manager Controller	1.6	0.4	0.2	+/- 0.8	+/- 0.2	+/- 0.1
Typical Steady-State Performance of Minimum CMG momentum & Attitude oscillation Blended Momentum Manager Controller	1.6	0.7	1.2	+/- 0.8	+/- 0.35	+/- 0.6

Microgravity Environment

The following illustration indicates typical observed microgravity characteristics.



Analysis concluded peak ELC rotations on the order of 0.03 degrees per axis (in the quiescent mode).

External Contamination

ISS provides an exceptionally clean environment to external payloads and science assets.

External contamination control requirements limit contaminant deposition to 130Å/year on external payloads and station sensitive surfaces.

Specified levels are lower than any previous space station (Mir, Skylab, Salyut) by several orders of magnitude. Measurements of contaminant deposition on ISS-returned hardware have demonstrated that requirements are met at station payload sites.

Experiment	Side	Requirement (130Å/year)	Measured
MISSE 2	ram	520 Å (4 years)	50 Å
	wake	520 Å (4 years)	500 Å
Node 1 nadir window cover	nadir	390 Å (3 years)	50 Å

Transportation to ISS

ISS Cargo Vehicles

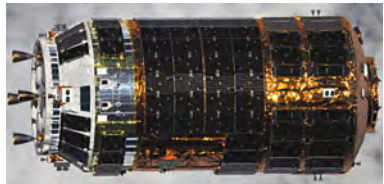
Several transport vehicles are available to launch payloads to ISS. When a technology demonstrator becomes a station payload, the ISS Program manifests the payload on the appropriate vehicle. Payload developers do not manifest directly with the launch provider for transport to ISS. Currently, only the SpaceX vehicle is capable of transporting external FRAM or CEPA payloads to ISS.



ATV (ESA) Cargo Capacity 5,500 kg



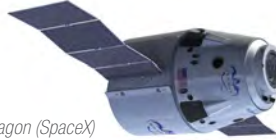
Soyuz



HTV (JAXA) Cargo Capacity 5,500 kg



Cygnus (Orbital Sciences Corp)
2,000 kg



Dragon (SpaceX)
Cargo Capacity 3,100 kg ascent

Payload Allowable Up-Mass & Volume Summary Table

Attach Payload Location	Allowable Payload Weight (including Flight Support Equipment)	Accommodation Weight (including adapter plate)	Total Weight	Payload Volume (W x H x L)
HTV Exposed Pallet (JEM EF Payload)	979 Lb (445 Kg)	121 Lb (55 Kg)	1100 Lb (500 Kg)	31.5" x 39.4" x 72.8" (800mm x 1000mm x 1850 mm)
HTV Exposed Pallet (ExPA, CEPA Payload)	See ExPA & CEPA payload specification for ELC & CEF	See ExPA & CEPA payload specification for ELC & CEF	*See ExPA & CEPA payload specification for ELC & CEF	*See ExPA & CEPA payload specification for ELC & CEF
ELC (ExPA)	490 Lb (222 Kg)	250 Lb (114 Kg)	740 Lb (336 Kg)	34" x 49" X 46" (863mm x 1244mm x 1168 mm)
Columbus (CEPA)	388 Lb (176Kg)	250 Lb (114 Kg)	638 Lb (290 Kg)	34" x 49" X 46" (863mm x 1244mm x 1168 mm)
JEM-EF	979 Lb (445 Kg)	121 Lb (55 Kg)	1100 Lb (500 Kg)	31.5" x 39.4" x 72.8" (800mm x 1000mm x 1850 mm)

Payload Integration Process

This section describes activities and information to assist prospective payload developers in formulating work plans, working with NASA to assess manifest options and ensuring a successful mission.

Application to ISS Technology Demonstration

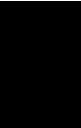
The first points of contact for investigations from other government agencies and commercially-funded demonstrations are the NASA National Lab Office and their agent, the Center for the Advancement of Science in Space (CASIS). Both work closely with the ISS Technology Demonstration Office.

All other organizations proposing to perform a technology demonstration on ISS should contact the ISS Technology Demonstration Office. Contact information and additional station information can be found at: http://www.nasa.gov/mission_pages/station/research/index.html

Those proposing to perform a technology demonstration on ISS are encouraged to use the information in this booklet to develop project goals, concept of operations and integration needs such as the resources or utilities that will be required from the ISS Program.

When contacting the ISS Technology Demonstration Office, please provide the following information as applicable to assist in evaluation.

1. Proposed payload name
2. Lead point of contact information
3. What capabilities are to be demonstrated
(project demonstration or scientific goals)?
4. How do these capabilities map to identified exploration needs
(not required, but please provide if applicable)?
5. Who are the sponsoring organizations?
6. Brief description of the demonstration: (Is it internal or external, what resources are required like power, data, etc.) What is the expected size/mass, and is there an expected time duration required in orbit?
7. When is it anticipated that the demonstration can be ready for turnover to the ISS Program for launch to ISS?



Once the initial contact is made, there may be further interactions to exchange information unique to the project. The ISS Technology Demonstration Office will notify the prospective payload developer of available station accommodations and launch opportunities and will make the appropriate manifesting and ISS integration approvals.

Mapping to Identified Need

The ISS Program intends to advance the state-of-the-art for as many technical areas as possible. It is desired that all advanced capabilities that can be demonstrated on the space station are identified. Proposers are encouraged to bring these advanced capability options to the ISS Technology Demonstration Office.

Though not a requirement, it is helpful to know when a technology demonstration can be linked directly to advancing identified exploration capability needs. When possible and appropriate, the technology payload developer should identify which technology area, discussed previously in this book, may be advanced by successful demonstration of the payload.

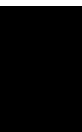
ISS Provided Assistance

Once the prospective payload developer has been sponsored by the ISS Technology Demonstration Office and identified as an ISS technology demonstration payload, the program will assign personnel to assist in completing the activities required to successfully integrate and perform the investigation on the space station.

Assigned Points of Contact

For each payload destined to be performed on the space station, there are several points of contact in the ISS Program identified to work directly with the payload developer. These points of contact will be identified after the payload has been sponsored by the ISS Technology Demonstration Office.

Technology Demonstration Lead: The Technology Demonstration lead is a member of the ISS Technology Demonstration Office. The technology demonstration lead will work with the payload developer to define the demonstration objectives and support the payload developer to ensure those technology demonstration objectives are met.



Payload Integration Manager (PIM): Each ISS payload is assigned a PIM who will be their main point of contact for all activities and interfaces to the ISS Program. The PIM will develop an integration schedule, identifying all the activities and products that will occur and be needed between the payload developer and the ISS Program. The PIM will communicate between all organizations and coordinate all the activities required for nominal integration of payloads into ISS.

Research Integration Manager (RIM): Each payload will be assigned a RIM. The RIM will assist with issues or unique needs that the payload developer may have from the ISS Program.

Payload Operations Lead: Each payload will be assigned a payload operations lead. This individual will be the interface to operations and will assist in developing in-orbit operational procedures, regulations, training and all other operational activities.

Safety Engineer (SE): The SE serves as the NASA Safety and Mission Assurance representative for station experiments/payloads. The SE reviews payload safety data packages (generated by the payload developer) to identify potential areas of noncompliance and technical safety issues. The SE supports and advises the payload developer and the chair of the Payload Safety Review Panel in the review and acceptance of payload hazard reports. The SE also coordinates technical interchange meetings and working group meetings to discuss and resolve technical issues between various technical representatives and payload providers. The SE supports the payload developers through the completion of safety review activities and assurance of flight readiness.

For the most up to date information on specific points-of-contact, please refer to http://www.nasa.gov/mission_pages/station/research/ops/research_information.html.

Hardware/Software Provided to Payload Developers

There are some standard hardware items that can be provided if available and requested by the payload developer. In most cases, the hardware items listed here are provided free of charge to the payload developer.

Internal payloads:

- Middeck Lockers – Lockers that will be installed in an EXPRESS rack can be provided to install the demonstration unique hardware.

External payloads:

- FRAMs or CEPAs – (depending on if the payload is destined for the ELC or Columbus EF respectively) A FRAM or CEPA is provided to attach the demonstration-unique hardware. The FRAMs and CEPAs provide interfaces to the launch vehicles and external station payload locations.

All payloads:

- TREK workstation – The TREK is a software suite required to interface to the ISS Payload Operations Center. All data and commanding from the payload will be routed through the TREK workstation. The user will need to add payload-unique software to read and manipulate the payload-unique commands and data. However, all interfaces with station operations are provided. The TREK system can be installed and operations performed at the user's desired location.

Payload developers will coordinate requests for hardware and services through their assigned PIM.

ISS Services

The ISS Program will provide the following services to assist with demonstration of the payload. These capabilities are generally provided free of charge to the payload developer.

- Launch to the space station
- Installation on station at identified site
- In-orbit utilities and operations support including crew or robotics time (if needed)
- Data handling and delivery (to the TREK)
- End-of-life removal and disposal

Hardware and Ground Handling Capabilities



Mostly utilized by larger external payloads, the ISS program has ground handling and ground support equipment that can be made available to payload developers. Lifting equipment, mobile mounting plates and other handling equipment may be utilized on an as-available basis, so payload developers do not need to design and build all this equipment.

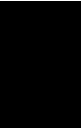
Use of this hardware can be requested and coordinated with the ISS Program through the PIM assigned to the payload.

Testing Capabilities

The payload developer is responsible for scheduling, resourcing and performing all tests of their payload system. When ISS test capabilities are requested, approval and scheduling the use of these assets can be negotiated with the ISS Program via the PIM assigned to the payload.

To assist in the software development of the payload, the ISS Program can provide small test equipment that emulates the space station side of the software interface. These systems are portable and can be used at the payload developer location. The systems are the Suitcase Test Environment for Payloads that simulates the space station facility interfaces; the EXPRESS Suitcase Simulator that simulates the EXPRESS/Window Observational Research Facility (WORF) Rack interfaces and the EXPRESS Logistics Carrier Suitcase Simulator that simulates the ELC interfaces.

The Payload Rack Checkout Unit (PRCU) is utilized to test payload experiment interfaces to ISS. In this capacity, the PRCU serves as a high-fidelity emulator of in-orbit station interfaces and allows experiment developers to ensure that their payload will interact properly once connected in-orbit. PRCUs provide interfaces to the standard station payload interfaces (120VDC, C&DH, video, Thermal, N2 supply and vacuum access). The PRCU is not portable.



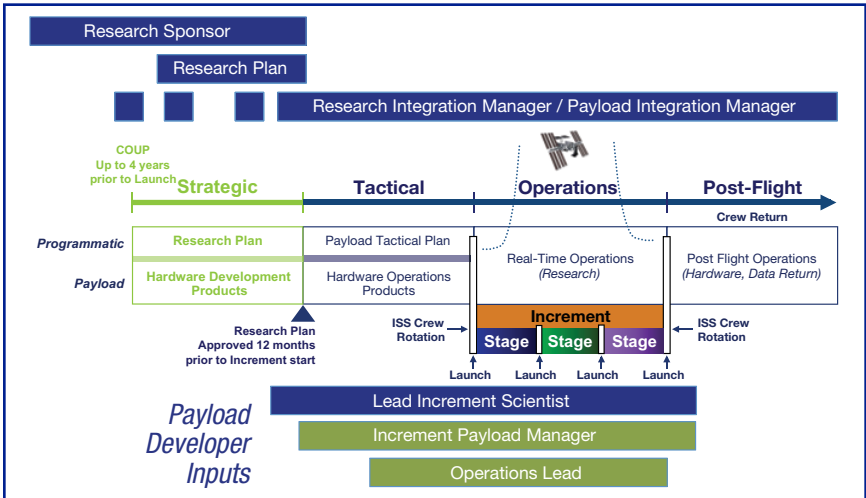
Tests with the PRCU can be conducted as near end-to-end tests. Data and commands are transmitted to the ISS Payload Operations Control Center and back to the payload's TREK work station to confirm data and commanding in the integrated system.

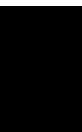
The EXPRESS Rack Functional Checkout Unit is utilized to test EXPRESS payload interfaces to the EXPRESS Rack. It provides flight-like interfaces for the structural/mechanical, power, data, thermal, vacuum and GN2 EXPRESS resources. It can be used to conduct end-to-end testing with the Payload Operations Control Center. It can also be used to test WORF power and data interfaces.

Top Level Payload Integration Milestones and Deliverables

Top level description of the milestones payload developers perform in the integration process (PIM schedule):

When a payload is sponsored by the ISS Technology Demonstration Office and a PIM is assigned to support the payload, the PIM will assist in developing an integrated schedule of activities with the ISS Program and the payload developer. Those details will be unique to each payload and each scheduled launch. The details cannot be accurately duplicated as a generic schedule and task description.





However, to assist in early project planning, listed below are many of the top level activities in which payload developers will participate. Payload developers can expect, at a minimum, to support the following activities:

- **Support research planning**

- Templates are provided by the ISS Program to assist the payload developer in providing the initial inputs (i.e.: mass, dimensions, experiment summary, estimates on crew time and power requirements.)
- Payload developers' efforts include filling out these templates with explanations of their system and on-orbit demonstration plan.

- **Document hardware and software interface requirements**

- Interface Requirement Documents and templates are provided as an initial step in the development of a unique station payload ICD.
- An ICD developer is assigned to each payload developer to aide in the generation of a unique payload ICD. The payload developer will provide payload specific information in these documents representing the system design and interfaces.

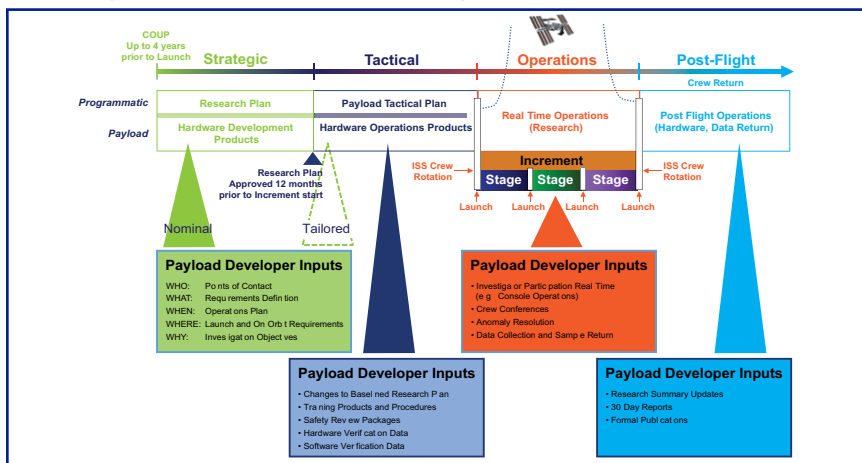
- **Interface requirements verification**

- Each payload developer will submit verification to show compliance to interface requirements (i.e.: power, data, thermal, robotics, launch environment, crew handling as defined in the payload unique ICD.)
- Each payload organization can request guidance on the approach to show compliance to interface requirements via the PIM and RIM, however, the payload developer is responsible for completing verification or approval of non-compliances.
- The payload developer is responsible for test labs and equipment. Where station-specific test hardware is required, the payload developer can coordinate this use with the PIM assigned to the payload.

- **Support station safety reviews for flight and ground activities**

- These reviews ensure safe operation of the payload during transport to ISS, while at the station and for any pre- or post-flight activities.

- Hazards that could be created by the payload system, or through its operations, are identified and reviewed in these safety reviews. The hazard controls provided by the payload developer to mitigate the identified hazards are also coordinated and approved in these reviews.
- Each payload developer will receive safety requirements and process documentation. From this data the payload developer will develop the safety data packages used in the safety reviews.
- Each payload developer will be assigned a safety engineer who will coordinate and guide the payload developer through the safety process.



- Support ground processing operations
- When required for launch vehicle integration or other pre- or post-flight operations, the payload developer will support activities to ensure that the payload systems are handled as desired.
- Each payload developer is expected to provide CAD, thermal and structural models of the payload
 - Payload models are used to support multiple station-integrated assessments.
 - These models are scheduled, described and documented in the PIM schedule and ICDs. Assistance in coordinating the details of these models will be provided by the PIM assigned to the payload.

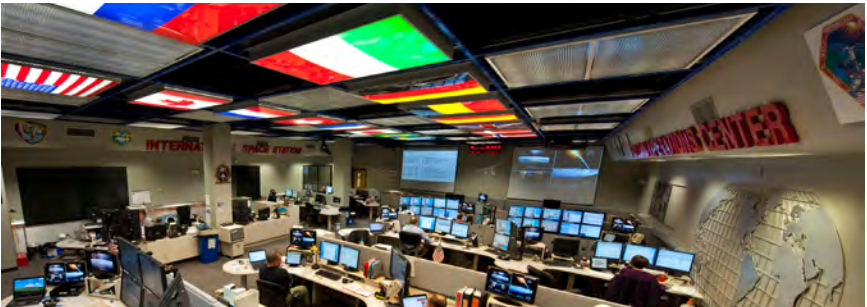
- **Participate in operations training**

- This participation ensures successful in-orbit operations. Payload training is provided by the ISS Program to the payload developer. This training provides guidance on how to operate through the Payload Operations Center, communicate with operators, schedule operations time and address off-nominal situations.
- Each payload developer will be provided an operations lead to aide in the generation of training products as well as other operational activities.

- **Provide input and develop operational procedures and flight rules**

- Inputs allow payload developers to ensure proper operation of their payload.
- Payload developers will provide system and concept of operations information to support development of procedures and rules.
- In cases where the crew interacts with the system, the payload developer will provide input for the development of the crew procedures.
- Each payload developer will be provided an operations lead to aide in the development of these and other operational products.

- **Operations**



- Payloads on ISS are operated by the payload developer and/or principal investigator in coordination with the Payload Operations Control Center.
- Payload developers operate their payload via the station-provided TREK system from any location desired. Payload operators are not required to be co-located with any ISS operations control center.

Acronyms

BAD	Broadcast Ancillary Data
C&DH	Command and Data Handling
CEPA	Columbus External Payload Adapter
ECLSS	Environmental Control & Life Support Systems
EEU	Experimental Exchange Unit
ELC	EXPRESS Logistics Carrier
ESA	European Space Agency
EVA	Extravehicular Activity (spacewalk)
EXPRESS	Expedite the Processing of Experiments for Space Station Rack
FRAM	Flight Releasable Attachment Mechanism
ICD	Interface Control Document
ICU	Integrated Communications Unit
ISS	International Space Station
JEM	Japanese Experiment Module
JEM-EF	JEM Exposed Facility
LEO	Low Earth Orbit
LOS	Loss of Signal
MCC	Mission Control Center
MSS	Mobile Servicing System
NASA	National Aeronautics and Space Administration
PIM	Payload Integration Manager
PL MDM	Payload Multiplexer De-Multiplexer
PRCU	Payload Rack Checkout Unit
RIM	Research Integration Manager
RMS	Robotic Manipulator System
SE	Safety Engineer
TDRSS	Tracking and Data Relay Satellite System
TEA	Attitude Torque Equilibrium Attitude
TREK	Telescience Resource Kit
TRL	Technology Readiness Levels
WOLF	Window Observational Research Facility

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10. Microbial Observatory
11. Microgravity Materials Research
12. Plant Science
13. Rodent Research
14. Space Environmental Effects
15. Technology Demonstration

For more information...

Space Station Science

<http://www.nasa.gov/iss-science>

Facilities

http://www.nasa.gov/mission_pages/station/research/facilities_category.html

ISS Interactive Reference Guide:

<http://www.nasa.gov/externalflash/ISSRG/index.htm>

Researchers

http://www.nasa.gov/mission_pages/station/research/ops/research_information.html



National Aeronautics and Space Administration

Johnson Space Center

<http://www.nasa.gov/centers/johnson>

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